Forest Policy and Economics 103 (2019) 36–44

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Assessment of timber supply under alternative contextual scenarios☆

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ARTICLE INFO

Keywords:
Forest management
Scenarios
Modelling
Economic assessment

ABSTRACT

Forest planners in former Eastern Block countries tend to provide conservative forecasts of timber supply, based on a rigid area control under the legislated rotation ages, and often assuming uniform forest management behaviour irrespective of the owner type. This study, in contrast, explores timber supply in a multi-disciplinary approach that analyses contextual factors and expands the space of future forest management options. Methodological steps include: (i) participatory development of qualitative scenarios, following different trajectories of contextual factors affecting forest management; (ii) identification of forest management programmes at the stand level; and (iii) modelling and economic assessment of future flows of timber at the landscape level. This research is carried out in a case study area (CSA) in central Lithuania containing 37,000 ha of forest, of which 80% is under state ownership. The development of forest resources was simulated for four contextualised scenarios: Business as Usual, Efficiency and Reforms, Ecology, and Climate Change Mitigation. Six forest-management programs were constructed together with stakeholders to describe the behaviour of state forest managers and private forest owners under each scenario. All four scenarios led to increased timber supply, largely due to the high proportion of middle-aged and premature stands in current forests. Notably, the present-day approach of rigid area control prioritises a steady timber supply through an evener age-class structure but largely fails on the last point. Our scenario analysis shows that relaxation of legislative requirements not only leads to increased long-term contribution to economic welfare but also enables achievement of evener age-class distributions.

1. Introduction

Scientific explorations of future management alternatives are faced with substantial uncertainty; however, the estimates can be brought closer to reality when the behavioural diversity of forest owners is explicitly included (Trubins et al., 2017). Further, quantitative modelling of owner behaviour can be linked with qualitative methods of scenario planning. The qualitative scenarios enable elaborating a set of possible, preferable and probable future developments (Schüll and Schröter, 2013). They are always hypothetical and explore future situations whose realization is not certain, but contingent. The scenarios can be used to bring the unconscious patterns and mindsets of decision-makers and stakeholders to the surface (Hengeveld et al., 2017). Consequently, the process of scenario development can spur original ideas contributing to novel developments in forestry.

Such innovative explorations of future are highly relevant in Lithuania, a country that since 1990 went through a radical socio-economic transition but whose forestry is still marked by ideological and institutional legacies of the Soviet period (Brukas, 2015). The production of woody biomass is considered to be the main marketed ecosystem service (ES), bringing the dominant share of income from forestry (Brukas et al., 2009). Annual removal of merchantable timber in 2010–2015 amounted to 6.7–7.4 mill. m^3 (Ministry of Environment and State Forest Service, 2016). According to the Ministry of Environment and State Forest Service (2016), the amount of felled timber in 2006–2015 was considerably lower than (~52.4%) the gross annual increment in the forests available for wood supply. In combination with the current age class structure (Fig. 1) this shows potential for increasing forest harvesting by at least 10–20% (Brukas et al., 2011).

Numerous drivers have shaped forest use in Lithuania during the last two decades. The economic transition, changes in forest resources and ownership structure are among the most important factors (Brukas et al., 2009). Current forest management planning is based on area

☆ This article is part of a special issue entitled. “Models and tools for integrated forest management and forest policy analysis” published at the journal Forest Policy and Economics 103C, 2019.

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https://doi.org/10.1016/j.forpol.2018.01.002
Received 21 October 2016; Received in revised form 2 January 2018; Accepted 9 January 2018
Available online 01 February 2018

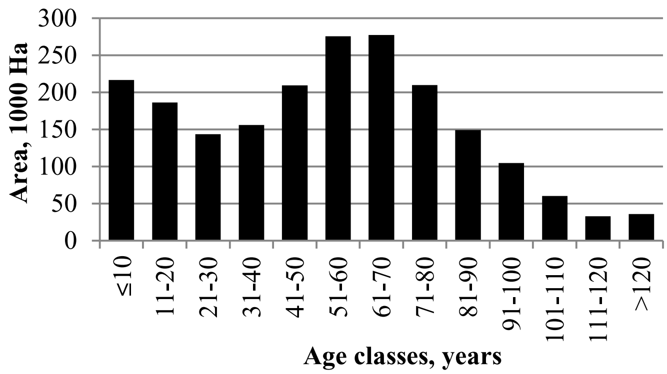

Fig. 1. Forest area distribution by age classes in Lithuania.

control, i.e. routine calculations of the age class distribution of forest stands under fixed rotations, largely disregarding the radical contextual changes due to the socio-economic transition after 1990. Illustratively, neighbouring Latvia adopted target-cutting diameters to meet contemporary market needs, while Lithuania continues to apply fixed rotation ages irrespective of site productivity, without any rational justification (Brukas, 2015). Similarly, existing forecasts of forest resource use are tied to current planning routines and legislative frameworks, often leading to conservative and largely failing forecasts (Brukas et al., 2009). To facilitate evaluation of future woody biomass availability and potential timber supply, European countries frequently apply decision support tools (Biber et al., 2015; Barreiro et al., 2016; Orazio et al., 2017). Developed more than a decade ago, the Kupolis simulator was used to assess the potential of Lithuanian growing stock and its use from 2001 to 2030 (Kuliešis and Petrauskas, 2000; Petrauskas, 2000; Petrauskas and Kuliešis, 2004). A “scenario” in these studies was associated with a set of forest-management aims, objectives and activities, assuming that all forest managers behave in the same way, irrespective of the ownership type or management objectives.

This study uses a set of qualitative scenarios to simulate different management behaviour of different forest owners and managers at a landscape or forest enterprise level. In contrast to conventional forecasts, our current study explores potential timber supply using a multidisciplinary approach including stakeholder inputs and linking the development of external socio-economic and political factors with plausible changes in approaches to forest management.

2. Material and methods

The methodological framework for this study is elaborated within the EU FP7 project INTEGRAL (Future-orientated Integrated Management of European Forest Landscapes; www.integral-project.eu). The steps of the study include:

- participatory development of qualitative scenarios, following different trajectories of contextual factors affecting forest management (Schüll and Schröter, 2013);
- identification of forest management programmes formulated at the stand level and associated with the scenarios (Stanislovaitis et al., 2015; Mozgeris et al., 2017);
- modelling and economic assessment of future timber flows (Mozgeris et al., 2015).

2.1. Case study area

The study was conducted in the Kazlų Rūda state training forest enterprise (TFE; Fig. 2) one of the 42 state forest enterprises in Lithuania. The total area within the Kazlų Rūda TFE amounts to ~66,000 ha, of which 36,785 ha is forested. State forests occupy 80% of the total forest area. Private forests and reserve for restitution make up 15% and forests managed by other state organisations (primarily military) take 5%. Forest stands dominated by pine, spruce, birch and black alder amount to 48%, 19%, 15% and 18%, respectively (Ministry of Environment and State Forest Service, 2016). By age, young stands occupy 22%, middle-aged 51%, pre-mature 10%, and mature 17%. The average age of forest stands is 56 years, with a standing stock of 238 m^3/ha and the annual increment of 7.2 m^3/ha. Mature forests, i.e. stands exceeding the minimum allowable rotation age (MARAs), average 301 m^3/ha. Area distribution by age class of the four most common tree species is illustrated in Fig. 3. Annual total timber volume harvested by all types of felling amounts to around 120,000 m^3, corresponding to 3.1 m^3/ha/year in 2015. The increment/harvesting ratio is thus 56%.

Fig. 2. Location of the case study area.

2.2. Contextual scenarios

We define a scenario as “… *the description of a future situation and the development or representation of the path from the present to the future*” (von Reibnitz, 1992). Since the 1970s, scenarios have been widely used by corporations as a versatile approach to consider alternative futures: decision-making is improved as managers can identify, consider and reflect on the uncertainties they might have to face. Scenarios may help to overcome errors, although it is impossible to eliminate all uncertainties (Varum and Melo, 2010). In the last 2–3 decades, the use of scenario planning has expanded to various audiences and fields, e.g. the public sector at various scales (Ringland, 2002; Star et al., 2016).

In our forestry application, the scenario development procedure involves the following methodological steps: (i) examination of forest management drivers with help of stakeholder interviews and desktop research; (ii) a stakeholder workshop to identify key factors influencing forest management and development of forested landscape; (iii) structural analysis of mutual influences among factors; (iv) examination of the alternative future manifestations of the aggregate factors; and (v) elaboration of scenario narratives (Schüll and Schröter, 2013). The qualitative interviews were carried out in autumn 2012, involving 28 informants: private forest owners, state forest managers from Kazlų Rūda TFE, forest inspectors and other forestry stakeholders. The informants were selected using snowball sampling (Goodman, 1961) with

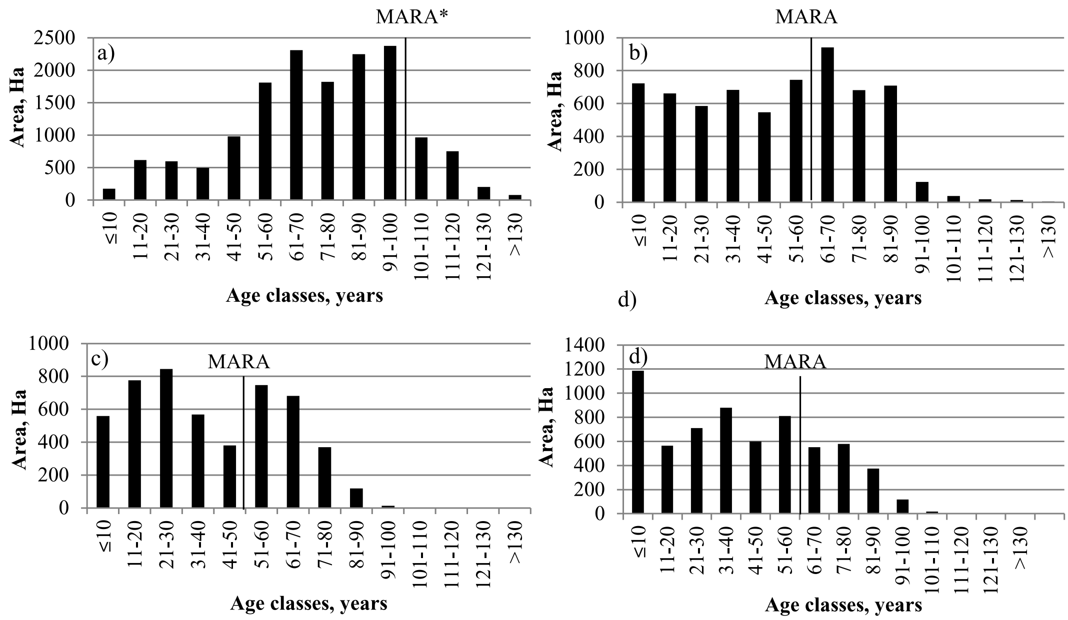

Fig. 3. Area distribution by age class of the most common tree species in Kazlų Rūda TFE CSA; a) pine, b) spruce, c) birch and d) black alder.

an aim to maximise the diversity of stakeholder perceptions. Interviews were digitally recorded with the informants' permission and typed notes were made during the conversation. The research team selectively transcribed relevant materials. Interview data were qualitatively analysed to elicit stakeholders' perceptions of forest management practices, key external drivers, most important ecosystem services, etc. Supported by documentary analysis of legislation, statistics and scientific publications, the analysis of interviews exposed important drivers behind forest management and forest development. These were compiled into a so-called STEEP table, describing the main Social, Technological, Ecological, Economic and Political factors at macro (national), *meso* (landscape) and micro (estate) levels.

As the next step, scenario construction involved a workshop engaging state forest managers, forest management planners, private forest owners, and other stakeholders in Kazlų Rūda TFE CSA. Moderated by 3 researchers, the workshop involved a total of 17 participants. Assuming a 30 year horizon (from 2013 to 2043), the stakeholders identified and scored the key factors influencing landscape development. They also conducted a structural analysis evaluating interactions between these key factors. The research team involving all authors of this study subsequently conducted factor clustering and identified aggregate factors and their possible future manifestations. For example, the aggregate factor “Market for Forest Products” included four possible future manifestations: High prices of all roundwood assortments; High prices of sawlogs; Low prices of all roundwood assortments; and Low prices of sawlogs. These aggregate factors are the key constituents of the scenarios, each scenario having a unique set of future manifestations for each identified factor (Table 3). The Parmenides EIDOS software (www.parmenides-eidos.com) (Schüll and Schröter, 2013) was used to assess the plausibility and internal coherence of possible combinations of future manifestations. Intended for strategic reasoning and solving of complex problems, the Parmenides EIDOS package was systematically employed for scenario building in 20 European case studies within the Integral project.

2.3. Quantitative assessment of scenarios

To link the qualitative scenarios and the quantitative projections of ES, each scenario is implied to predefine the behaviour of a forest owner or manager who may: (i) migrate between the owner/manager types, and (ii) chose a certain forest management program that depends on the forestry objectives of state forest managers and private forest owners. Importantly, owners and managers can manage different parts of their estates differently, i.e. we do not need to assume a uniform behaviour by an owner. The scenarios assume the shares of state and private forest ownership remain stable. Six forest management programs (FMPs) were defined for the case area based on the empirical interview and desktop material, consultations with foresters of Kazlų Rūda TFE and forest management planners, as well as our expert judgment (Table 1).

Current forest management regime (forest distribution by forest groups and subgroups) and the ownership type were considered as the main criteria to allocate a forest compartment to a certain FMP under the specific scenario. In many cases the scenarios prescribed a shift of forest compartment into a different forest group or subgroup. A set of behavioural rules for both state and private forests was elaborated to allocate forests among the forest management programs in various proportions. Such allocations rested on materials from scenario development workshops, opinions of interviewed stakeholders and expert judgment.

2.4. Modelling future flows of timber supply

The development of forest resources and the timber supply for five decades starting from 2013 was simulated for each scenario using the Kupolis simulator (Petrauskas and Kuliešis, 2004). Kupolis is an open system consisting of modules (artificial regeneration, natural regeneration, thinning, final harvest, economic evaluation) were each subsystem can simulate a different type of forest management program at the stand level (Kuliešis et al., 2017). An exception is the module of final cutting budget that generates optimal solutions at forest management unit level, and uses aggregated age class data. The annual budget of final cuttings is re-optimized at each step using the principles of dynamic programming, while other forest management activities are modelled using iterative simulations.

The basic unit of simulation is a forest stand or compartment, originating from the Lithuanian stand-wise forest inventory. The number of forest compartments in the Kazlų Rūda TFE CSA totals 18,574, each compartment having a detailed characterisation with more than 100 variables including administrative, soil, and stand descriptors.

The different FMPs were implemented in Kupolis in two ways: (i) editing the subgroup code for a compartment in the database, thus

Table 1
Forest management programs.

Forest management program (FMP)	Forestry objectives	Specifications
FMP 1.	Current forest management practice in State forests belonging to groups IV (timber production) and III (protective). Prioritising timber production while ensuring environmental and protective functions.	Annual allowable cut from final felling is estimated so that mature stands are cut in 10 years, i.e. mature forests will be aging. Reforestation follows silvicultural recommendations depending on soil type and using traditional technologies. Pre-commercial thinnings follow silvicultural requirements, however the commercial thinning is conducted as late as possible, aiming for maximal timber removal.
FMP 2.	Current forest management practice in the state forests II group (special purpose forests). Ecosystem protection and recreation are top priorities. Forests for restitution are included here.	No clear final felling is permitted and the cutting age corresponds to the natural maturity age.
FMP 3.	Current forest management practice in state forests, group I. Natural forest development	No forestry activities.
FMP 4.	Active management for nature. Priority for functions other than timber production.	Annual allowable cut from final felling is low. Priority is given to non-clear final felling, natural regeneration and tending for mixed forest stands. Frequent thinnings of all types, however the thinning intensity is low.
FMP 5.	Intensive forestry. Seeking to maximise profit within the current legal framework.	The forest management program mimics “Swedish-style forestry” but following currently valid legal acts. Maximal allowable cut with low reserve of mature forest. Priority for planting conifers and birch. Intensive pre-commercial thinnings, the 1st commercial thinning conducted at the highest possible intensity but postponed as much as legally possible. The 2nd commercial thinning is as intensive as possible.
FMP 6.	Liberal state forestry with changed legal requirements. Maximum profit from state forests.	Cutting age reduced by 20%. All other specifications are the same as for the FMP1.

implicitly re-assigning a specific forest management regime for a compartment, and (ii) modifying the setting files. Key settings to define FMPs are summarized in Table 2. In the most radical forest utilisation alternative, FMP6, the age of final felling was reduced by ~20%, automatically modifying the limits of forest maturity groups. The first commercial thinning was delayed by 5–10 years, also increasing the proportion of selective felling by 20%.

Simulations were performed for all combinations, Scenario x FMP x Owner type. New databases corresponding to years 2013, 2023 and so on were generated which were later examined using standard functionality of the database management system L and Kupolis or exported to dbf formats for further processing.

2.5. Economic assessment of timber supply

Development and use of forest resources was simulated in Kupolis every 10 years from 2013 to 2063. The simulator has built-in functionality to deliver output estimates of profits. The required input parameters include afforestation costs, reforestation costs and tending costs of young stands in EUR/ha, costs of intermediate and final fellings in EUR/m^3, and income from intermediate and final fellings in EUR/m^3, differentiated by dominant tree species (pine, spruce, oak, ash, birch, black alder, aspen and grey alder). The parameters are elaborated based on financial information provided by Kazlų Rūda TFE. The structure of assortments is calculated for each tree species using Tebėra (1987) methodology. Forest yield tables by Petrauskas et al. (2010) are used to determine the volume of timber assortments. Cash flows are discounted by applying a 2% interest rate as recommended by Brukas et al. (2001) for Lithuanian forestry.

2.6. Assessment of age-class structure

As an age class we assume 10-year long stand age intervals, i.e. the 1st age class ranging from 1 to 10 years, the 2nd age class – from 11 to 20 and so on. The age-class structure is a determinant of the forest resource development and the Lithuanian forest policy stresses the importance of pursuing even age-class structure. We assess the deviation of age-class structure at a certain time from the targeted equal age-class area distribution, using the so-called *K index* (Vitunskas, 1988):

$$K = 1 + \frac{1}{N}\sum_{i=1}^{N}\frac{F_i - F_T}{F_T \times 10^{(i-1)}} \tag{1}$$

where:

F_i – the area of ith age class;
i – the ranking number of the ith age class, starting from the mature forests (mature and over-mature forests are considered to belong to the same age class, for which $i = 1$).
N – the number of age classes in the rotation;
F_T – the target area of each age class aiming for even (or other) area distribution by age classes.

Table 2
Key settings to define the forest management programs in the Kupolis simulator.

Felling type	Factors limiting forest utilisation	Forest management programs (FMP)			
		FMP1&2	FMP4	FMP5	FMP6
Final felling	The time (in years) during which all mature conifers and noble hardwoods have to be harvested after reaching MARA[a]	5	20	1	10
	The time (in years) during which other mature hardwoods have to be harvested after reaching MARA	1	20	1	10
Intermediate felling	Target relative stocking index of conifers and noble hardwoods	0.9	0.8	0.8	0.9
	Target relative stocking index of other hardwoods	0.8	0.7	0.7	0.8
	Target stocking could be exceeded by, %	1	10	10	1
	% allowed to cut under the target stocking	30	10	20	30

[a] Minimum allowable rotation age.

Table 3
Alternative future manifestations of aggregate factors depending on scenario.

	Aggregate factors and their manifestations									
Scenario	Population	European Union (EU) policy	National regulation	Economic instruments	Market for forest products	Forestry framework	Infrastructure	Public opinion (PO)	Private forestry	State forestry
Business as usual	Stagnant population	EU focus on environment protection	Focus on environment protection	Subsidies for non-forestry services	High prices of forest products	Framework not changing	Infrastructure development	Radicalisation of PO	Mergers of estates	Bureaucratic model
Efficiency and reforms	Growing population	EU vs. the rest of the world	Economic- oriented intensive forestry	Tax increase for state forest enterprises	High prices of forest products	Orientation to market	Infrastructure development	Green society	Rapid consolidation of estates	New public management with territorial restructuring
Ecology	Depopulation	EU focus on environment protection	Focus on environment protection	Subsidies for non-forestry services	Low prices of forest products	Reduction of management intensity	Infrastructure development	Radicalisation of PO	Rapid consolidation of estates	New public management with no territorial restructuring
Climate change mitigation	Stagnant population	EU against climate change	Focus on environment protection	Subsidies for non-forestry services	High prices of forest products	Framework not changing	Infrastructure development	Passive society	Mergers of estates	Bureaucratic model

The value of K is 1.0 if the distribution of age classes is perfectly equal. The index exceeds 1 when the share of mature and premature forest stands is high, while it goes below 1 in the landscapes dominated by young and middle-aged stands.

3. Results

After considering a multitude of possible development trajectories, the following scenarios have been constructed: Business as Usual, Efficiency and Reforms, Ecology, and Climate Change Mitigation. The Business as Usual scenario is considered as a reference, following current trends of forest landscape development. Efficiency and Reforms expects immediate radical economic reforms aiming to improve the efficiency of forestry in private and especially in the state sector. Among other liberalization measures, it incorporates a 20% reduction of cutting age. The Ecology scenario anticipates forest management and timber production to meet growing concerns for environmental protection. Climate Change Mitigation juxtaposes growing timber industries and increasing environmental concerns. Future manifestations of different factors influencing forest landscapes in Kazlų Rūda TFE are summarized in Table 3.

Table 4 summarizes the behaviour of state and private forest managers via the choice of FMPs under each scenario.

The total volume of the growing stock increases under the Ecology and Business as Usual scenarios during three decades. However, it starts declining under the Efficiency and Reforms and Climate Change Mitigation scenarios in the third decade (Fig. 4.a). The 20% reduced cutting age, as assumed in the Efficiency and Reforms scenario, results in the lowest standing timber volume accumulation, while the largest volumes are accumulated under the Ecology scenario. The total volume accumulated in mature forests (Fig. 4.b) tends to increase under all scenarios except Efficiency and Reforms. It should be noted that the total volume of mature forests in 2013 is nearly twice as large under Efficiency and Reforms than in any other scenario. This is due to the fact that the definition of "mature forest" in Lithuanian forestry is directly dependent on the minimum allowable rotation age (MARA). The reforms assumed by this scenario include reducing MARAs by 20%, automatically increasing the proportion of mature forests. All scenarios, except Ecology, cause decreasing average stand age (Fig. 4.c). The changes are most drastic under Efficiency and Reforms.

All scenarios lead to decreasing incomes and profits (Fig. 5). By the end of the simulation period, Efficiency and Reforms is the most profitable scenario; Business as Usual and Ecology are the least profitable, yielding approximately 13% less profit than Efficiency and Reforms. The Climate Change Mitigation scenario, which involves some liberalization of forest management within the current legal framework, generates 10% higher total profit compared to Business as Usual in 2063.

Timber use in pine stands in coming decades is strongly influenced by the relatively large amounts of currently premature forest stands (Fig. 6.a). None of the scenarios manages to level out the age-class distribution in pine forests (Figs. 6.a and 8.a). State forestry is more profitable per unit area than private lands only under the Business as Usual scenario (Fig. 7). Profits from private forests are larger (by 5–30%) under all other scenarios.

Currently, the K *index* is above 1 (Fig. 8), indicating dominance of premature and mature forest stands. It should be noted that there are two lines in Fig. 8 displaying the trends of the K *index* under conditions of the "Efficiency and Reforms" scenario referring to different number of age classes in the rotation. However, all scenarios results in evener age class areas in spruce, birch and black alder stands (Figs. 6.b–d and 8.b–d). Steep declines of the K index during the first three decades of the simulation are observed in spruce, birch and black alder stands no matter the scenario; the Efficiency and Reforms scenario leads to the most even age class structure. After 2043, the decline slows down or even stops, except under the Efficiency and Reforms and Business as

Table 4
Forest manager behavioural matrixes for each scenario.

Manager type	% of area under given forest management program (FMP)					
	FMP1	FMP2	FMP3	FMP4	FMP5	FMP6
Business as usual						
State forest manager	95.2	4.8				
Private forestry	98	2				
Efficiency and reforms						
State forest manager		4.8		12.9		82.3
Private forestry	31.5	2				66.5
Ecology						
State forest manager		0.3	4.5	95.2		
Private forestry	66.5	2		31.5		
Climate change mitigation						
State forest manager		13.2	4.5		82.3	
Private forestry	31.5	2			66.5	

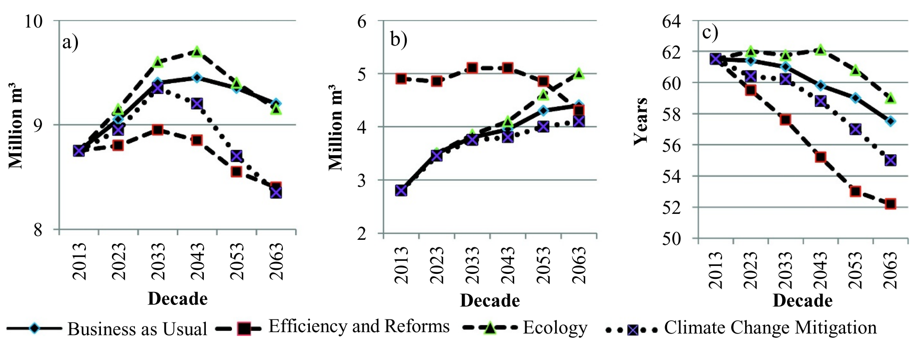

Fig. 4. Dynamics of the total growing stock volume (a), volume of mature stands (b), and average age (c).

Usual scenarios in deciduous stands. This may warn of resource overuse in the distant future.

4. Discussion

Even though the scenarios elaborated here prescribe rather different futures, the basic outputs – the trends of profit from the timber supply – follow quite similar trajectories. Though some of the scenarios assumed modifications in the forestry framework, such as market orientation (Efficiency and Reforms) or reduction of forest management intensity (Ecology), they did not influence the underlying forestry paradigm in Lithuania very strongly.

The paradigm involves even-aged forest management with MARA, fixed for each tree species according to technical maturity, and not differentiated by site productivity (Brukas et al., 2011). Silvicultural measures are prescribed in multiple legal acts whose first aim is to achieve the highest large dimension timber yield possible in the final fellings. Annual cutting amounts are calculated for state forestry lands based on area control with an explicit aim to even out the age class structure (Brukas et al., 2011). Outcomes would obviously differ in the case of a radically different approach to forest management, such as introducing target diameter cuttings instead of area control. Such an idea could fit the Efficiency and Reforms scenario very well. However, future factors were defined by stakeholders possibly obviating ideas that necessitate radical changes to the forestry paradigm.

The current age-class structure in Kazlų Rūda TFE seems to be the main factor shaping the profitability of timber. A large proportion of middle-aged and premature pine forests in combination with strictly-fixed MARAs (e.g. 101 years for Scots pine in production forests) inhibits levelling out of the age class structure. It should be noted that Efficiency and Reforms spurred the need to deal with "legally" increased amounts of mature and overmature forest due to the reduced final cutting age. The scenarios assume that certain management programs are applied immediately and there is some ambiguity introduced in choosing the value of N in formula (1). Reduced MARAs under the conditions of the Efficiency and Reforms scenario automatically yield more mature and over-mature forests shifting the respective trend line upward in Fig. 8. To maintain comparable trajectories of *K index* development between all scenarios, an extra line is used to display the levelling out of age-class areas for the Efficiency and Reforms scenario.

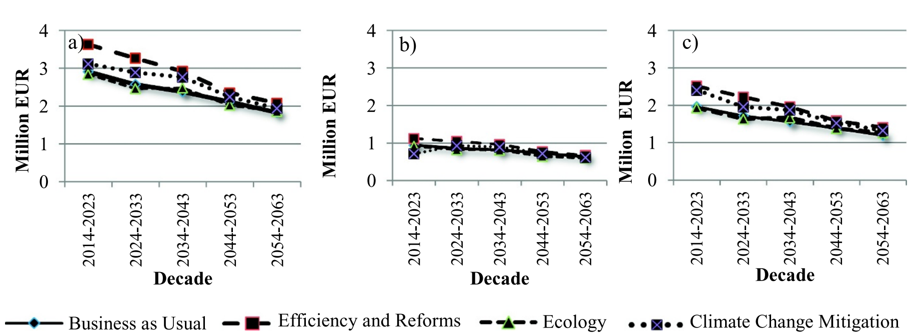

Fig. 5. The dynamics of incomes (a) costs (b) and profits (c) under different scenarios.

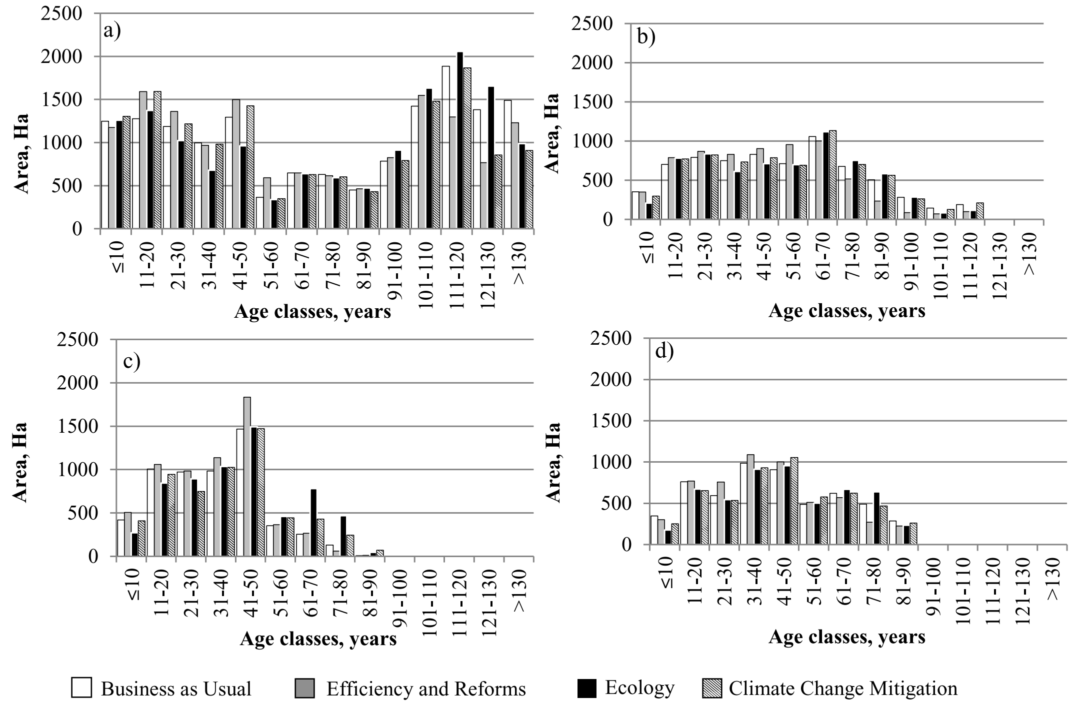

Fig. 6. Distribution of forest area by age classes in 2063; a) pine, b) spruce, c) birch and d) black alder.

This line assumes the same number of age classes in the rotation as the remaining three scenarios do, with the increased amounts of forests becoming available for final felling due to the reduced final cutting age. Both trend lines of the *K index* for the Efficiency and Reforms scenario follow similar trajectories. The age class structure based on currently valid final cutting ages is best levelled out by relatively large harvests in Kazlų Rūda TFE (Efficiency and Reforms scenario), and the proportion of premature and mature birch stands is even over-reduced.

The scenarios were elaborated for a 30 year period, which was considered distant enough from the present to reflect long-term changes in the socio-economic context; but close enough so that stakeholders could still reasonably balance future uncertainties with their knowledge of the past and present. The simulations, in contrast, were carried out for a longer horizon of 50 years, keeping the scenario parameters fixed throughout the period. The longer horizon of simulation enables assessing longer-term impacts of scenarios that are inherently slow to manifest regarding the forest condition.

It was assumed that the management conditions of a certain scenario apply immediately, which is rather unrealistic. Even under such an assumption, the changes of forest characteristics were relatively minor during the first 2–3 decades, while more significant effects emerge during the second half of the simulation period.

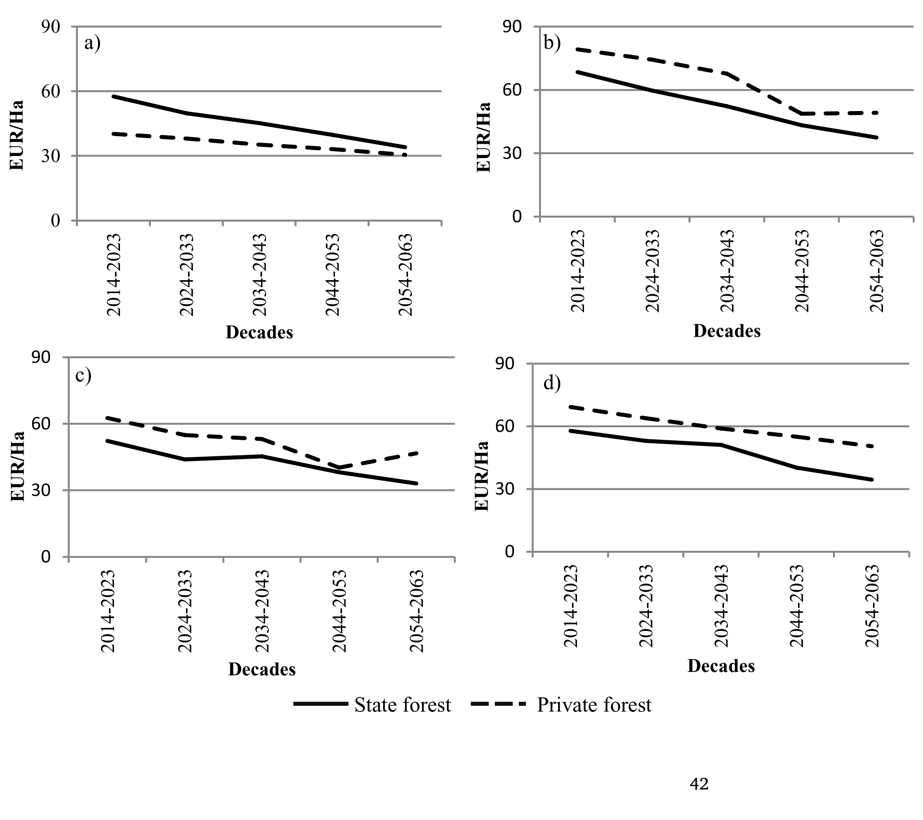

Fig. 7. The dynamics of profit from timber supply in state and private forests under different scenarios; a) business as usual, b) efficiency and reforms, c) ecology, and d) climate change mitigation.

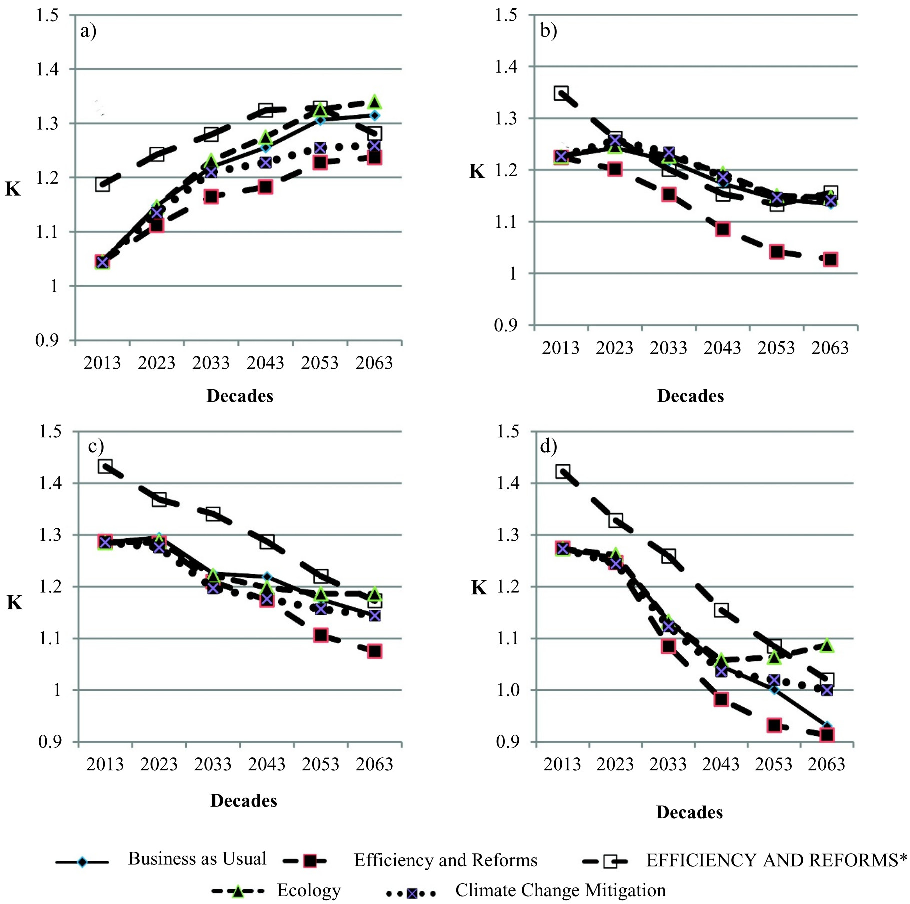

Fig. 8. Dynamics of the evenness of age class distribution under different scenarios; a) pine, b) spruce, c) birch and d) black alder. The line referring to the Efficiency and Reforms scenario and identified with the * displays the trajectory of *K index* development assuming reduced final cutting age.

It should be mentioned that the dynamics of simulated forest characteristics and the *K index* changed only after three modelling steps under some scenarios. The shapes of the forest resource and timber supply trajectories are much influenced by the current state of forest resources; this indicates that the horizons of the qualitative contextual scenarios and the forest modelling do not need to coincide. In practical terms, the number of possible iterations or simulation steps in “Kupolis” is unlimited. The modeller should, however, bear in mind the increasing uncertainty with each additional simulation step.

Recent studies in forest management planning propose that stakeholders need to be involved in decision making and negotiations, and not only be informed about the outcomes of planning (Carpentier et al., 2017; Borges et al., 2017). Our study represents a humble attempt to involve forest stakeholders in active consideration of future approaches to forest management and surrounding contexts, still a rare exercise in the post-socialist realm. Although there is a long way to go to a genuine and systematic inclusion of multiple interests, our study demonstrated a feasible method that exposed alternative options to future utilisation, while generating enthusiasm among participants. The chosen scenarios proved that higher economic welfare and more even long-term forest utilisation might be achieved by waiving overly strict legal requirements.

5. Conclusions

The qualitative methods of scenario development were linked with quantitative projections of timber supply, applying a forestry decision support system and modelling the behaviour of state and private forest owners. All four scenarios – Business as Usual, Efficiency and Reforms, Ecology, and Climate Change Mitigation – generated increasing nominal profits from timber production. Trends of timber supply and profit strongly depend on the age structure of forest resources, reinforced by the planning based on area control.

This study demonstrates a methodology that links qualitative contextual scenarios with quantitative simulations of forest resources, which is a recent strand in the forest planning literature. Most importantly, it reveals novel paths for thinking about the future that can serve as catalysts for modifying conservative forestry traditions. This wide area of research provides many possible threads for future studies, such as empirically-grounded specification of forest management programmes according to different types of private forest owners or exploring the ways to institutionalise novel methodologies into forest management planning that is still entrenched in institutional legacies of the socialist period.

Acknowledgment

This study is part of the INTEGRAL research program – Future-oriented integrated forest management of European forests, funded by the European Commission's 7th Framework Programme, grant agreement no FP7-282887.

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